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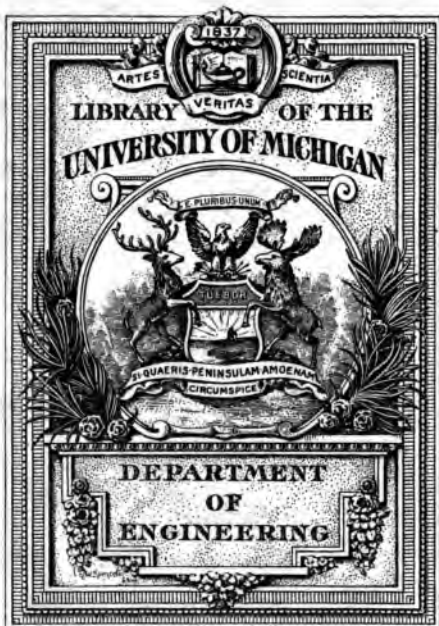
FOG SIGNALS.

A PAPER READ BEFORE THE PHILOSOPHICAL SOCIETY OF
WASHINGTON, OCTOBER 22, 1881

BY ARNOLD E. JOHNSON.
Chief Clerk of the Light House Board.

WASHINGTON:
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1882.



THE GIFT OF
Arnold B. Johnson

Mr. A. B. JOHNSON presented the following communication on

RECENT INVESTIGATIONS BY THE LIGHT-HOUSE BOARD ON THE
ANOMALIES OF SOUND FROM FOG SIGNALS.

Among our erroneous popular notions is one which occasionally brings practical men, even ship-masters, to grief. It is the idea that sound is always heard in all directions from its source according to its intensity or force, and according to the distance of the hearer from it. Instances of this fallacy have accumulated, and they are emphasized by shipwrecks caused by the insistence of mariners on the infallibility of their ears, who have accepted unquestioned the guidance of sound signals during fog as they have that of light-houses during clear weather. The fact is, audition is subject to aberrations, and under circumstances where little expected. We have learned by sad experience that implicit reliance on sound signals may, as it has, lead to danger if not to death.

The wreck of the steamer Rhode Island, on Bonnet Point in Narragansett Bay, which happened on November 6, 1880, when a million dollars in property was lost, was caused, it was said, by the failure of the fog-signal on Beaver Tail Point to sound at that time. Thereupon the Light-House Board, which has charge of the sixty and more fog-signals on our coasts, made an investigation which showed that the fog-signal was in full operation when the wreck took place; but it also brought out the fact, that while there was no lack in the volume of the sound emitted by the signal, there was often a decided lack in the audition of that sound, so much so that it would not be heard at the intensity expected, nor at the place expected; indeed it would be heard faintly where it ought to be heard loudly, and loudly where it ought to be heard faintly; that it could not be heard at all at some points, and then further away it could be heard better than near by; that it could be heard and lost and heard and lost again, all within reasonable ear shot, and all this while the signal was in full blast and sounding continuously.

The following table, A, will give the results obtained by the officer of the navy who investigated these phenomena, and reported to the Light-House Board:

TABLE A.

Observations on Beaver Tail Fog-Signal, Rhode Island, made on November 16, 1880, from a sail-boat, Thermometer at beginning 58°, ending 67°; Wind moderate from the West; Weather clear and cold, with a bright sun. Time, beginning 11.15 A. M.

Number of Observation.	Distance from Beaver Tail Fog-Signal in statute miles.	Intensity of sound in scale of 10.	REMARKS.
1	$\frac{1}{2}$	10	
2	$\frac{3}{8}$	2	
3	$1\frac{1}{4}$	1	
4	$1\frac{1}{4}$	10	
5	$1\frac{3}{8}$	1	
6	$1\frac{1}{2}$	0	
7	$1\frac{3}{8}$	0	
8	$1\frac{1}{8}$	1	Close to Bonnet Point changed course and ran almost due south.
9	$1\frac{1}{8}$	1	$1\frac{1}{2}$ miles from last station.
10	1	0	$\frac{1}{4}$ mile from last station.
11	$\frac{7}{8}$	1	" " "
12	$\frac{3}{8}$	4	" " "
13	$\frac{1}{2}$	10	" " "
14	$\frac{3}{8}$	10	About opposite Beaver Tail, $\frac{1}{2}$ mile from last station, and in the axis of trumpet.
15	$\frac{1}{2}$	10	About $\frac{1}{2}$ mile from last station, and running for Newport, heading nearly northeast.
16	1	10	About $\frac{1}{2}$ mile from last station.
17	$1\frac{1}{4}$	5	" $\frac{1}{2}$ " "
18	$1\frac{1}{2}$	2	" $\frac{1}{4}$ " "
19	$1\frac{7}{8}$	2	" $\frac{1}{4}$ " "
20	$2\frac{1}{8}$	1	" $\frac{1}{2}$ " "
21	$2\frac{1}{2}$	0	" $\frac{1}{4}$ " "
22	$3\frac{1}{2}$	0	" $\frac{1}{2}$ " "
23	$3\frac{3}{8}$	2	" $\frac{1}{2}$ " "
24	4	10	About $\frac{1}{4}$ mile from last station, just off Ft. Adams.
25	$4\frac{1}{4}$	10	Under the lee of Fort Adams.
26	$4\frac{1}{2}$	2	
27	$4\frac{3}{8}$	2	
28	$4\frac{3}{4}$	2	
29	5	2	Newport.

Last summer, I had an opportunity while on a light-house steamer, to experience something of the variations in the audition of the Beaver Tail fog-signal. When the steamer left the light-

house landing, the fog-signal was to sound for a given time, and to commence when the steamer had reached a given point, half a mile distant. When that point was reached, we could see by the steam-puffs coming from the 'scape pipe, that the signal was being blown; but we could not hear its sound; nor did we, as we continued on our course, running away from the light station for the next five minutes. When near to Whale Rock, less than a mile and a half distant from the signal, the steamer was stopped, silence was ordered fore and aft, and we all listened intently. The expert naval officers thought they heard a trace of the fog-signal, but my untrained ears failed to differentiate it from the moan of the whistling buoy close to us. Yet the blasts of the ten-inch steam whistle, for which we were listening, can often be heard at a distance of ten miles.

Soon after, I had another opportunity to further observe the operations of this signal. We left Narragansett Pier, R. I., on Aug. 6, 1881, at 4 P. M., in a dense fog, with a strong breeze from the W. S. W., and a heavy chop sea. We wished to ascertain how far the Beaver Tail fog-signal could be heard dead to windward and in the heaviest of fogs. At Whale Rock, one and one-third miles from it, we did not hear a trace of it. Then the steamer was headed directly for Beaver Tail Point, and we ran slowly for it by compass, until the pilot stopped the steamer, declaring we were almost aboard of the signal itself. Every one strained his ears to hear the signal but without success; and we had begun to doubt of our position when, the fog lifting slightly, we saw the breakers in altogether too close proximity for comfort. We passed the point as closely as was safe; and, when abreast of it and at right angles with the direction of the wind, the sound of the fog-signal broke on us suddenly and with its full power. We then ran down the wind to Newport, and carried the sound with us all the way. The fog continuing during the next day, the signal kept up its sound, and we heard it distinctly and continuously at our wharf, though five miles distant.

On the night of May 12, 1881, about midnight, the *Galatea*, a propeller of over 1500 tons burden, with a full load of passengers and freight, bound through Long Island Sound from Providence to New York, grounded in a dead calm and a dense fog on Little Gull Island, about one-eighth of a mile from and behind the fog-signal, and got off two days later without damage to herself or loss

of life or freight. It was as usual alleged that the fog-signal, a steam siren, at Little Gull Light, was not in operation at the time of the accident, and the Light-House Board, also, as usual, immediately ordered an investigation. This was made by the Assistant Inspector of the Light-House District, a naval officer, who reported that after taking the sworn evidence of the light-keepers at Little Gull and the other light-stations within hearing distance, of other Government officers who were, for the time being, so located that they might have had knowledge of the facts, and of the officers of vessels that were within ear shot, including those of the Galatea, he reached the conclusion that the fog-signal was sounding at the time of the accident; and that, although the fog-signal was heard at Mystic, fifteen miles distant in another direction, and although it was heard on a steam tug a mile beyond the Galatea; that it was heard faintly, if at all, on that vessel; and if heard at all, was so heard as to be misleading, though the Galatea was but one-eighth of a mile from the source of the sound.

This report is in itself full of interest. It appears that this officer spent several days steaming around Little Gull, while the fog-signal was in full blast, in various kinds of weather, and that he found the aberrations in audition here were as numerous and even more eccentric than those before mentioned as experienced at Beaver Tail. The results of his observations are given in Tables B and C; and in each case the condition of the atmosphere as to humidity, pressure, temperature and motion are shown, as is also the then tidal condition.

TABLE B.

Fog Signal Tests at Little Gull Island, Long Island Sound, July 11, 1881. Time 10 A. M. Wind, N.N.E., force 2. Barometer, 29.77; Thermometer, 61. Weather at commencement, dark, overcast with squalls of Scotch mist from N.N.E. It began to clear at 11:30 A.M.

Number of Observation.	Time of Observation.	Distance from Little Gull Island fog signal in stat. miles.	Intensity of sound in scale of ten.	REMARKS.
1	<i>h. m.</i> 10 10	1 $\frac{5}{8}$	1	A faint murmur is put at $\frac{1}{2}$ of 1, in scale of 10.
2	10 15	2 $\frac{3}{8}$	$\frac{1}{2}$	
3	10 18	2 $\frac{1}{2}$	0	
4		3 $\frac{3}{8}$	0	

Number of Observation.	Time of Observation.	Distance from Little Gull Island fog signal in stat. miles.	Intensity of sound in scale of ten.	REMARKS.
5	h. m.			
6	10 25	3 $\frac{5}{8}$	0	
7		3 $\frac{1}{2}$	0	
8	10 50	3 $\frac{1}{2}$	$\frac{1}{2}$	About $\frac{1}{2}$ mile from last station.
9		3 $\frac{5}{8}$	1	
10		3 $\frac{5}{8}$	0	About $\frac{1}{2}$ mile from last station.
11		3 $\frac{5}{8}$	1	About $\frac{1}{2}$ mile from last station.
12	11 09	3 $\frac{1}{2}$	2	Changed course and ran a little S. of W.
13		3 $\frac{1}{2}$	2	
14	11 15	3 $\frac{1}{2}$	3	
15	11 25	2 $\frac{7}{8}$	3	
16		2 $\frac{1}{2}$	4	
17	11 35	2 $\frac{3}{4}$	5	
18		2 $\frac{1}{2}$	7	
19		2 $\frac{1}{8}$	7	
20	11 55	1 $\frac{1}{2}$	8	
21		$\frac{1}{2}$	9	
22	12 03	$\frac{1}{2}$	10	About $\frac{1}{2}$ mile from last station.
23	12 07	$\frac{3}{8}$	10	
24		$\frac{3}{8}$	7	
25	12 14	1 $\frac{7}{8}$	2	
26	12 19	1 $\frac{7}{8}$	1	
27	12 23	2 $\frac{1}{4}$	1 $\frac{1}{2}$	Changed course.
28	12 23	2 $\frac{3}{4}$	$\frac{1}{2}$	Faint murmur.
29	12 40	2 $\frac{1}{4}$	$\frac{1}{2}$	Changed course.
30	12 52	3 $\frac{1}{2}$	0	
31	1 01	2	$\frac{1}{2}$	
32	1 06	1 $\frac{5}{8}$	1-2	
33	1 12	1 $\frac{5}{8}$	5	
34	1 18	$\frac{3}{4}$	10	
35		$\frac{3}{8}$	10	Almost west of fog-signal.
36	1 35	1 $\frac{1}{4}$	10	
37		1 $\frac{1}{2}$	8	Changed course.
38	1 42	1 $\frac{3}{8}$	8	
39	1 52	$\frac{7}{8}$	10	Stood N. E. ; sound gradually increasing.
40	1 55	$\frac{1}{2}$	3	
41		$\frac{7}{8}$	2	Changed course.
42	2 01	$\frac{3}{4}$	2	
43	2 02	$\frac{3}{8}$	2	
44		$\frac{7}{8}$	10	
45		$\frac{3}{4}$	10	
46		$\frac{3}{4}$	8	
47		1	7	
48	4 29	1 $\frac{3}{4}$	5	
49		2	2	
50	4 38	2 $\frac{3}{4}$	1	
51		3 $\frac{3}{8}$	0	Lost the sound.
52	4 45	3 $\frac{3}{8}$	0	
		4 $\frac{1}{4}$	0	Bartletts Reef light-ship; wheels stopped and no sound.

TABLE C.

Observations at Little Gull Island, Long Island Sound, July 15, 1881, commencing at 6.30 A. M. Thermometer, 59° Fahr. Barometer, 29.80. Wind, W.N.W., force 3, hauling to the westward and increasing gradually.

Number of Observation.	Time of Observation.	Distance from Little Gull Island fog-signal in stat. miles.	Intensity of sound in a scale of ten.	REMARKS.
	<i>h. m.</i>			
1	6 32	1 $\frac{3}{4}$	10	
2	6 57	2 $\frac{1}{4}$	10	Changed course, running S. by W. $\frac{1}{2}$ W.
3		2 $\frac{1}{4}$	8	About $\frac{1}{2}$ mile from last station.
4		2 $\frac{3}{8}$	7	
5		3 $\frac{1}{4}$	4	
6	7 17	3 $\frac{3}{4}$	3	Changed course, running E.
7		3 $\frac{5}{8}$	2	About $\frac{1}{2}$ mile from last station.
8		3 $\frac{3}{4}$	1	" " "
9		3 $\frac{1}{2}$	5	" " "
10	7 28	3 $\frac{5}{8}$	7	Changed course, running N. by W. $\frac{1}{2}$ W.
11		2 $\frac{1}{2}$	8	
12		2 $\frac{1}{2}$	5	About $\frac{1}{2}$ mile from last station.
13		2	5	Changed course, running W.
14	7 50	2 $\frac{3}{4}$	5	
15		2 $\frac{7}{8}$	3	
16		3 $\frac{1}{8}$	2	
17	8 00	3 $\frac{3}{4}$	0	Sound lost.

On August 3d, I had an opportunity to hear this fog-signal myself, and to note its audibility. The wind was from the south and very light; the air was damp, smoky, hazy, and, as the sailors say, hung low; the barometer stood at 29.90; the tide was about flood. Our steamer was run for six miles in the axis of the siren's trumpet, which was sounded for our benefit at its full force. Note was made every third minute in a scale of ten of the intensity of the sound, and it was found that the audition decreased normally with the distance for the first two miles; at 2 $\frac{1}{2}$ miles it had fallen off one-half; at 3 miles it had fallen to one-tenth its power; at 3 $\frac{1}{4}$ miles away we could hear but a faint murmur, and when 4 miles distant, we had lost it completely; and yet there seemed to be no reason why we should not have heard it clearly at three times that distance.

The next morning was calm, but heavy with white fog; yet we heard the Little Gull siren distinctly though it was 10 $\frac{1}{2}$ miles off, as we lay at our dock in New London. The steamer ran out of the

harbor, but was compelled to anchor so thick was the fog ; yet we heard Little Gull though $7\frac{1}{2}$ miles off, at a force of 6 in the scale of ten, and the sound was so clear cut and distinct that we could differentiate it from the siren at the New London light, which was much nearer to us. The steamer worked round to inspect the neighboring lights, and we heard the Little Gull siren when at North Dumpling light station, 7 miles off, at a force of 6 ; at Morgan's Point Light, 10 miles off, at a force of 5, and we continued to hear it at an intensity of from 5 to 6 as we worked around among the other lights, within a compass of 10 miles, till the fog broke and the siren ceased.

Opportunity soon occurred for making more critical experiments. On a fine day we ran out to Little Gull, had the siren started under full steam, and then, following out a pre-arranged program, ran round Little Gull Island in such way, as to describe a rectangle of about 8 by 10 miles, its longest side running nearly north and south. No fixed rate of speed was maintained, but the steamer slowed, backed, or stopped, as was necessary. The atmosphere was what the sailors call lumpy, and Prof. Tyndall calls non-homogeneous. Prof. Henry, when writing of a like condition, said : * "As the heat of the sun increases during the first part of the day, the temperature of the land rises above that of the sea, and this excess of the temperature *produces upward currents of air*, disturbing the general flow of wind, both at the surface of the sea and at an elevation above." Observations were made and noted in a scale of ten, of the force or intensity of the signal's sound as it reached us at the end of each minute. The following Table D shows a sufficient number of the results for our purposes, taken from the tabulated schedule of our notes. The table also shows the condition of the atmosphere during our observations.

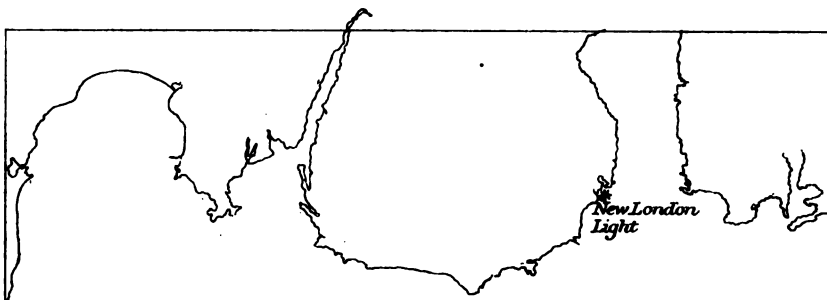
*L. H. Board's Rep. for 1875, page 116.

TABLE D.

Observations at Little Gull Island, Long Island Sound, August 9, 1881, commencing at 10 A. M. Thermometer—Dry Bulb, 73°.09, Wet Bulb, 73° Fahr. Barometer, 29.77 Wind, S.W., force, 3. Cir. Strat. Clouds about the horizon.

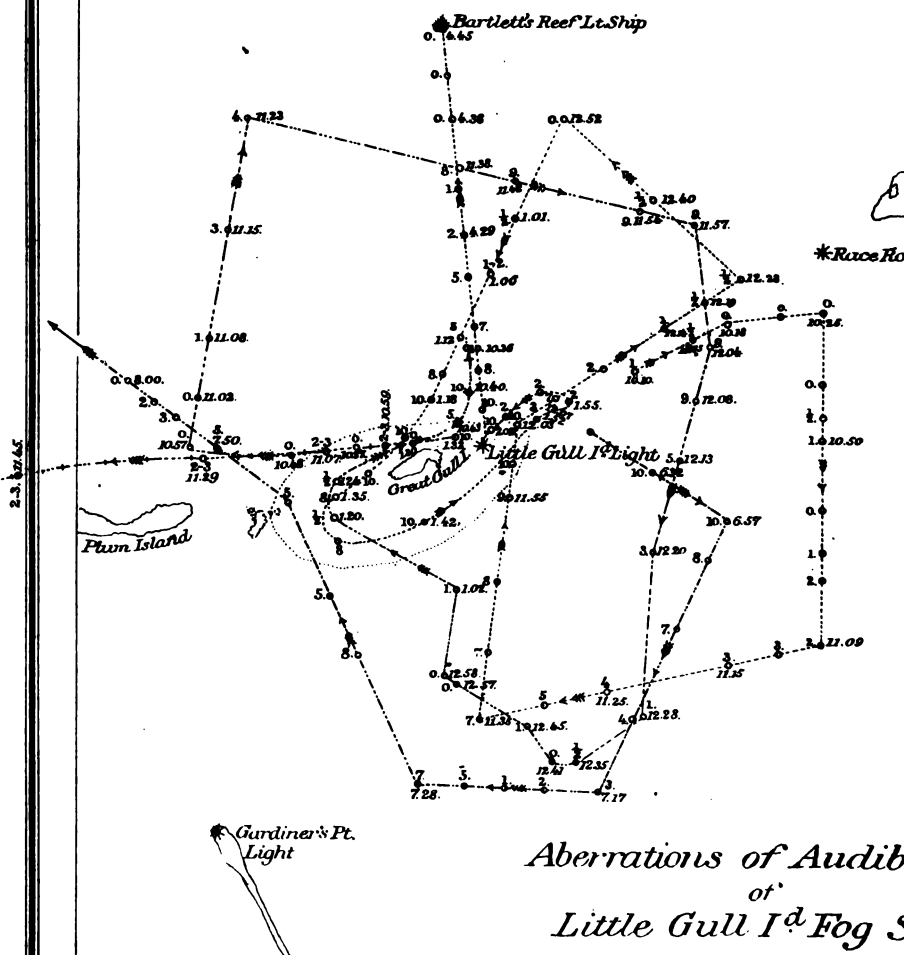
Number of Observation.	Time of Observation.	Distance from Little Gull Island in statute miles.	Intensity of sound in scale of ten.	Number of Observation.	Time of Observation.	Distance from Little Gull Island in statute miles.	Intensity of sound in scale of ten.
	<i>h. m.</i>				<i>h. m.</i>		
1	10 30	0 $\frac{1}{4}$	10	16	12 04	2 $\frac{5}{8}$	9
2	10 32	0 $\frac{1}{2}$	10	17	12 08	2 $\frac{1}{4}$	9
3	10 34	0 $\frac{1}{2}$	10	18	12 13	2 $\frac{1}{8}$	5
4	10 36	1	10	19	12 20	2 $\frac{1}{8}$	3
5	10 37	1 $\frac{1}{4}$	0	20	12 28	3 $\frac{1}{4}$	1
6	10 48	2	0	21	12 35	3 $\frac{1}{2}$	0 $\frac{1}{2}$
7	10 57	3	0	22	12 41	3 $\frac{3}{8}$	0
8	11 02	3	0	23	12 45	3	1
9	11 08	3 $\frac{1}{3}$	1	24	12 57	2 $\frac{1}{2}$	0
10	11 15	3 $\frac{1}{2}$	3	25	12 58	2 $\frac{3}{8}$	0
11	11 23	4 $\frac{1}{8}$	4	26	1 02	1 $\frac{1}{2}$	1
12	11 38		8	27	1 20	1 $\frac{3}{4}$	0 $\frac{1}{2}$
13	11 42	2 $\frac{3}{4}$	9	28	1 24	1 $\frac{5}{8}$	0 $\frac{1}{2}$
14	11 54	3	9	29	1 30	0 $\frac{3}{4}$	0
15	11 57	3 $\frac{1}{4}$	9	30	1 32	0 $\frac{1}{4}$	10

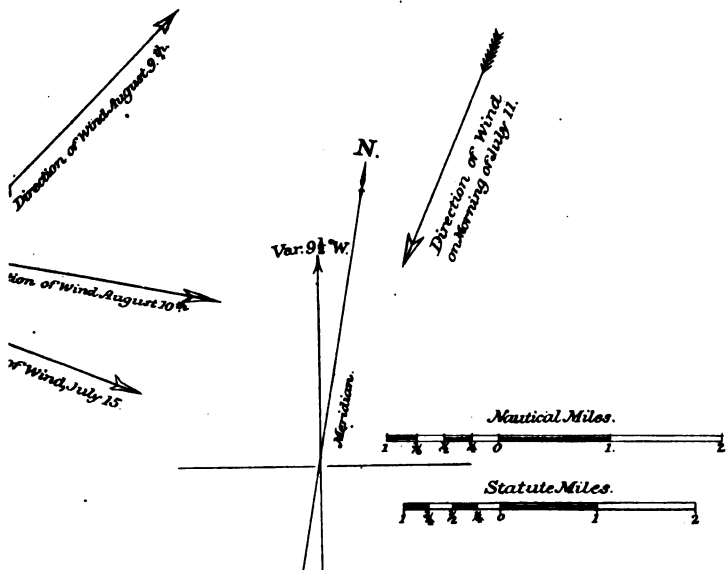
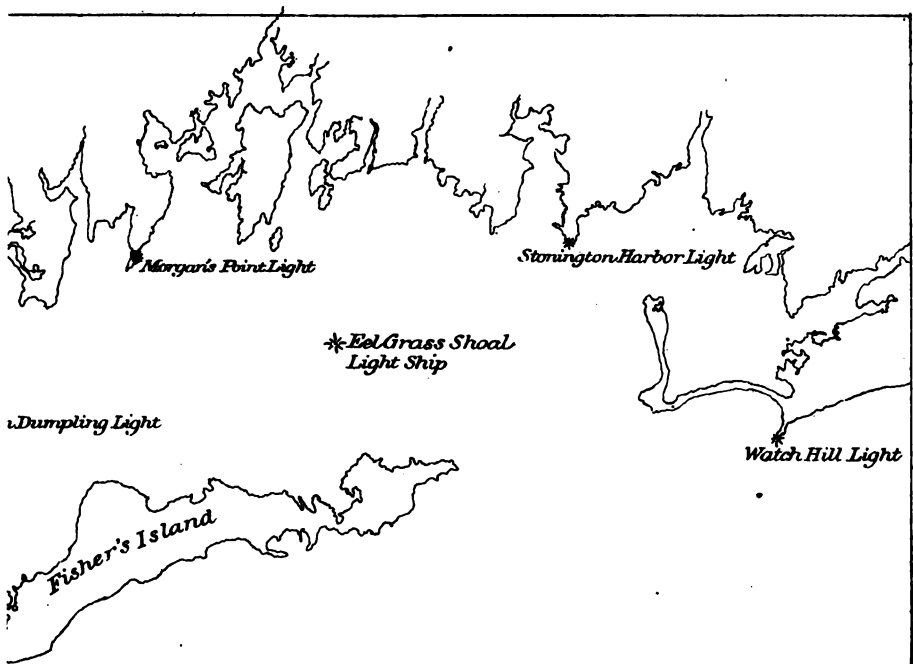
At 4 P. M. two of us went in a row boat to Little Gull from the steamer which lay to her anchor half a mile off, and verified the fact that the fog-signal had been in full operation during the time of our observations by the report of the steamer's mate, who had been left there for that purpose. It then occurred to us to investigate still more closely what appeared to be a space—a circle of silence—in which we had, during the experiments of the morning, failed to hear the signal. After having had the siren put in full operation again, we pulled toward the nearer end of Great Gull Island, the siren sounding meantime with earsplitting force. When about 600 yards away we suddenly lost the sound as completely as if the signal had stopped. Pulling toward the steamer, not more than 200 yards, we reached a position at right angles with the axis of the siren's trumpet when we suddenly heard the sound again at its full force. Thus, in pulling 500 yards, we passed from complete audition of the signal to absolute inaudition; and then we passed back again to complete audition by pulling 200 yards in



Table

B	July 11 th 1881.
C	July 16 th 1881.
D	August 9 th 1881.
E	August 10 th 1881.





another direction. All this took place within half an hour in open water, always in full view of the signal station, and without any visible obstacle being interposed or removed.

While on the island we learned that one of the light-house keepers, who had been on leave, had just returned from Sag Harbor, twenty miles away to the southeast. He had failed to hear the signal at all, until opposite the eastern end of Great Gull Island, and until he was within half a mile of the siren which was in full operation.

On the next morning our steamer anchored about a mile north of Little Gull; the wind was light, the air was clear, and the day was warm and beautiful. As it had been preceded by a warm night the atmosphere was homogeneous, and it was expected that we should have a day of normal audition and barren of curious phenomena. After the siren had commenced its noise we ran down to a point within half a mile of the light-house, and then steamed for Plum Island, running a little south of east for six miles, when we returned as nearly as might be on our own track. The results were curious. We lost half the force of the sound when within a quarter of a mile of the siren; a moment later we had lost four-fifths of it. Running another half mile we were off the middle of Great Gull Island, and the sound had increased to a force of four; in five minutes more it had dropped to three; from that on, until we reached the end of our six mile run, it gradually weakened, and it had dropped to a force of two when we turned and ran back to our anchorage. It is particularly curious that the sound had the same intensity at three-sixteenths of a mile from its source, and at six whole miles from that point, while it varied from two to ten in a scale of ten between those points. The results of the trip are more fully and exactly given in Table E.

Thinking that possibly this peculiarity might have been induced by those differences of temperature in the strata of the atmosphere suggested by Dr. Tyndall as probable cause for such phenomena, effort was made to ascertain something of these differences by sending a thermometer to the upper air. In the course of the afternoon we made a kite some six feet high, attached to it a self-registering thermometer, and after a number of trials succeeded in getting it up about five hundred feet, and in hauling it safely in again after it had been up over an hour. The thermometer had a wet bulb, and beside was protected from the direct rays of the sun; but it

registered only half a degree more of heat at its highest point than it had done in the pilot-house. The course the kite took showed no difference between the air currents aloft and aloft.

TABLE E.

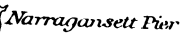
Observations at Little Gull Island, Long Island Sound, August 10, 1881, commencing at 10:30 A. M. Dry Bulb Thermometer, 76°, Wet Bulb, 75°. Barometer, 29.40. Wind, W. by N., force 3, and steady throughout. Day clear and beautiful.

Number of Observation.	Time of Observation.	Distance from Little Gull Island in a direct line in statute miles.	Intensity of sound in a scale of ten.	Number of Observation.	Time of Observation.	Distance from Little Gull Island in a direct line in statute miles.	Intensity of sound in a scale of ten.
	<i>h. m.</i>				<i>h. m.</i>		
1	10 36	1 $\frac{1}{8}$	10	7	10 59	2 $\frac{1}{8}$	2 to 3
2	10 40	0 $\frac{3}{8}$	10	8	11 07	2 $\frac{3}{8}$	2 to 3
3	10 44	0 $\frac{1}{2}$	5	9	11 29	2 $\frac{5}{8}$	2 to 3
4	10 45	0 $\frac{5}{8}$	2	10	11 45	5 $\frac{1}{8}$	2 to 3
5	10 49	0 $\frac{7}{8}$	4	11	11 52	5 $\frac{1}{2}$	2
6	10 53	1 $\frac{1}{8}$	3	12	12 02	6	2

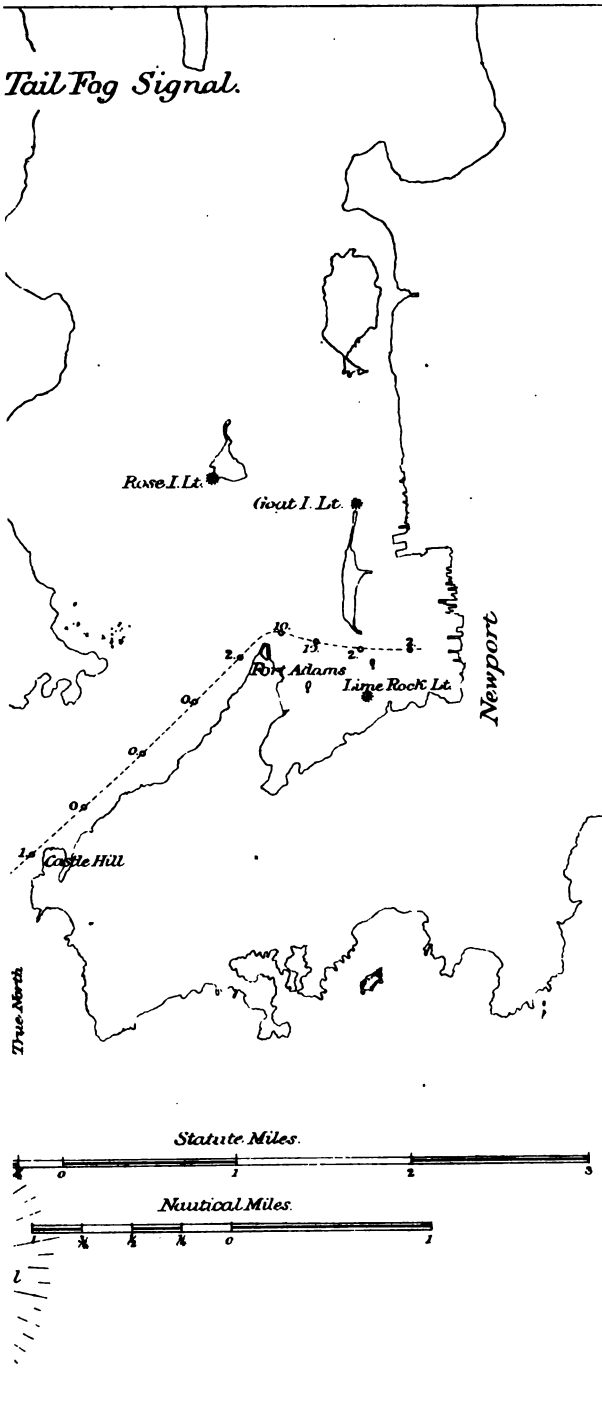
The Light House Board has known from the first that aberrations in audibility might occur near any fog-signal. When the fog-trumpet was set up at Beaver Tail Point in 1856, the Naval Secretary of the Board, then Lieutenant, now Rear Admiral Jenkins, U. S. N., in company with Mr. Daboll, its inventor, found, in returning to Newport, that they lost the sound of the signal between Beaver Tail and Fort Adams, and recovered it again between the Fort and Newport, as did later observers, and that this failure to hear it did not result from any failure of the signal to operate.

The Board's publications show that Prof. Henry, its scientific adviser, had the subject for many years continuously under advisement, and that between 1865 and 1878, many experiments were made, and various reports on them were submitted to the Board, as to the use and value of its several kinds of fog-signals. In 1870 the Board directed General Duane, of the U. S. Engineers, then and still in its service, to make a series of experiments to ascertain the comparative value of its different signals. In his report the General said, speaking of the steam fog-signals on the coast of Maine:

Table A. November 16th 1941



Tail Fog Signal.



* "There are six steam fog-whistles on the coast of Maine; there have been frequently heard at a distance of twenty miles, and as frequently cannot be heard at the distance of two miles, and this with no perceptible difference in the state of the atmosphere.

"The signal is often heard at a great distance in one direction, while in another it will be scarcely audible at the distance of a mile. This is not the effect of wind, as the signal is frequently heard much farther against the wind than with it; for example, the whistle on Cape Elizabeth can always be distinctly heard in Portland, a distance of nine miles, during a heavy northeast snow-storm the wind blowing a gale directly from Portland toward the whistle."

* * * * *

"The most perplexing difficulty, however, arises from the fact that the signal often appears to be surrounded by a belt, varying in radius from one to one and a half miles, from which the sound appears to be entirely absent. Thus, in moving directly from a station, the sound is audible for the distance of a mile, is then lost for about the same distance, after which it is again distinctly heard for a long time. This action is common to all ear-signals, and has been at times observed at all the stations, at one of which the signal is situated on a bare rock twenty miles from the main land, with no surrounding objects to affect the sound."

Prof. Henry, in considering the results of Gen. Duane's experiments, and his own, some of which were made in company with Sir Fred'k Arrow and Capt. Webb, H. B. M. Navy, both of the British Light-House Establishment, who were sent here to study and report on our fog-signal system, formulated these abnormal phenomena. He said they consisted of:

"1. The audibility of a sound at a distance and its inaudibility nearer the source of sound.

"2. The inaudibility of a sound at a given distance in one direction, while a lesser sound is heard at the same distance in another direction.

"3. The audibility at one time at a distance of several miles, while at another the sound cannot be heard at more than a fifth of the same distance.

"4. While the sound is generally heard further with the wind than against it, in some instances the reverse is the case.

"5. The sudden loss of a sound in passing from one locality to another in the same vicinity, the distance from the source of sound being the same."†

These experiments were not confined to our own shores. Dr. Tyndall, the well known English physicist, who stands in the same relation to the British Light-House Establishment that Prof. Henry did to our own, writes thus:

* Annual Rep't L. H. Board 1874, pp. 99-100.

† L. H. B. Annual Rep. 1875, page 106.



"With a view to the protection of life and property at sea, in the years 1873 and 1874, this subject received an exhaustive examination, observational and experimental. The investigation was conducted at the expense of the Government, and under the auspices of the Elder Brethren of the Trinity House [the governing body of the British Light-House Establishment.]

"The most conflicting results were at first obtained. On the 19th of May, 1873, the sound range was $3\frac{1}{3}$ miles; on the 20th it was $5\frac{1}{2}$ miles; on the 2d of June 6 miles; on the 3d more than 9 miles; on the 10th 9 miles; on the 25th 6 miles; on the 26th $9\frac{1}{4}$ miles; on the 1st of July $12\frac{1}{4}$ miles; on the 2d 4 miles, while on the 3d, with a clear, calm atmosphere and smooth sea, it was less than 3 miles."*

The officer who made the reports, as to the fog-signals at Beaver Tail and Little Gull, after the accidents to the steamers Rhode Island and Galatea heretofore mentioned, was the Assistant Inspector of the Third Light-House District, Lieut. Comd'r F. E. Chadwick, U. S. N.; and it was he who had charge of the Light-House steamer while the foregoing observations were being made, after Capt. George Brown, U. S. N., the Inspector—to whom I am indebted for many courtesies on this trip—was called elsewhere by other official duties. Mr. Chadwick brought to this work an unbiased mind, trained in the severest schools of scientific investigation. His object in all his experiments was simply to ascertain the exact truth for practical official purposes. He had not proposed, even to himself, to make any generalizations from his observations. But he kindly answered certain of my questions as to the opinions which had forced themselves upon him, and his answers are here set down for the consideration of those who use these fog-signals overmuch as a guide for their ships.

"It seems to me" he said "that navigators should understand that when attempting to pick up a fog-signal attention must be given to the direction of the wind, and that if they are to windward, (in a moderate breeze,) the chances are very largely against hearing it, unless close to; that there is nearly always a sector of about 120° to windward of the signal in which it either cannot be heard at all, or in which it is but faintly heard. Thus, with the wind E. S. E., so long as they are bearing from the signal between N. E. and South, there is a large chance that the signal will not be audible until it is very close.

"As they bring the signal to bear at right angles with the wind, the sound will almost certainly in the case of light wind increase, and it will soon assume its normal volume—being heard almost without fail in the leeward semicircle.

"Fog, to my mind, and so far as my experience goes, is not a factor of any consequence whatever in the question of sound. Signals may be heard at great dis-

*Sound, by Tyndall, 3d Edition English, page 324.

